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which I can not come nearer and nearer to accounting for completely." The series π is never completed, yet any one term of it, which you can name, may be exactly computed. My own argument does, I think, escape this objection. It attempts to point out a well-verified character about facts which is not simply at present unexplained in detail, but would seem to be inexplicable in terms of causation, even to a perfect knowledge. The tendency to deviate, to spread out, to produce ever new sports, is indeed in substantial agreement with the Jacobean doctrine of a growing universe. But I do not think the inadequacy of any given concepts, or group of concepts, to account for motion, change, or life, can be regarded as a proof of a real spontaneity in those facts.

And the present argument goes even further. There seems to me no ground for saying that there is anything about spontaneity which is unintelligible, *i. e.*, beyond clear conception. Chance as here defined appears to be clear enough. It is a dual affair, with a collective and an individual aspect, and in my view each of these aspects is meaningless without the other. The collection is law-abiding, the individual members, within limits, ambiguous. But I do not see why ambiguity is not a perfectly clear concept. There would seem to be, then, no real reason for excluding spontaneity from the kingdom of the intellect. It should be included as a genuine scientific category, no more wonderful than law itself. Not the limitation of the understanding by something indefinable, mysterious, unaccountable, but the inclusion of that something within the sphere of clear definition, is what every thinker naturally desires.

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EXPERIMENTAL ORAL ORTHOGENICS: AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF DENTAL TREATMENT ON MENTAL EFFICIENCY[1]

LITTLE if any attempt has hitherto been made to measure by scientific, objective means the mental improvement resulting from the correction or removal of the various physical defects which are now generally known to afflict the majority of school children. We are beginning to appreciate, from a number of recent studies, the extent of the retarding effect upon mental growth of such physical anomalies as adenoids, hypertrophied tonsils, nasal obstructions, defective ears, eyes, and mouths; but no one has attempted to determine experimentally the precise orthogenic effects which are believed to ensue from a definite course of combined prophylactic and operative treatment. And yet our whole system of medical school inspection and treatment must ultimately justify itself by its *demonstrated, verifiable* results—not by the opinions and assumptions, based on unaided observation, of schoolmasters, or medical inspectors, or school patrons, but by the comparable scores of a system of verifiable and demonstrable objective measures.

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[1] Read before Section L, Education, of the American Association for the Advancement of Science, Washington, December 29, 1911.

In the present paper we shall give a very brief sketch of the results of an attempt to determine by scientific, mental measures the influence of hygienic and operative dental treatment upon the intellectual efficiency and working capacity of a squad of 27 public-school children in Cleveland, Ohio (10 boys and 17 girls), all of whom were handicapped, to a considerable degree, with diseased dentures or gums and an insanitary oral cavity.[2] These children were the recipients of free dental treatment at the hands of the Cleveland Dental Society and the National Dental Association during the course of the experimental year, which began in May, 1910, and closed in May, 1911. The treatment included not only the filling of dental cavities, the treatment of the gums, the brushing of the teeth and gums after each meal, and the sanitation of the oral cavity, but the thorough fletcherizing of the food. Oral euthenics contemplates not only mouth sanitation and the carpentry of the teeth, but the complete mastication of the food. Instruction relating to mouth hygiene and correct eating habits was given at the school (Marion) by the chairman of the Oral Hygiene Committee of the National Dental Association (Dr. W. G. Ebersole), together with two demonstration meals. Follow-up work was done by an employed nurse, for the purpose of giving individual advice and instruction to parents and pupils, and for the purpose of ascertaining whether the pupils were faithfully following the instructions.

This research, it may be added, was the outgrowth of the nation-wide school oral-hygiene campaign inaugurated in Cleveland in March, 1910, by the National Dental Association. My own connection with the movement consisted in suggesting, contriving and giving (in person or by proxy) five series of psychological efficiency tests at stated intervals during the experimental year. These tests were designed to measure any improvement or increase, which might result from the practise of the oral hygiene regimen sketched above, in the power of immediate recall (immediate visual memory span), in the capacity to form spontaneous and controlled associations, in the ability to add, and in the ability to perceive, attend, and react to, certain visual impressions.

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[2] A more complete discussion of this research appears in "Experimental Oral Euthenics," *The Dental Cosmos,* April and May, 1911, pages 404 ff. and pages 545 ff.

In the memory test the pupils were required to memorize, during a period of 45 seconds, as many figures as possible. 10 figures, each containing 3 digits, in large print on a cardboard were displayed before the class. Exactly one minute was allowed for writing. This test is thus based on the use of non-sense materials and furnishes a measure of the immediate visual memory span.

In the spontaneous association test the pupils were provided with a sheet of paper containing a column of 30 simple, every-day words. At a given signal they were told to turn the papers right side up and write opposite each word the first word suggested by it, irrespective of whether or not the suggested word was logically connected with the supplied antecedent or key-word. The time allowed was 85 seconds. The number of words written in a test like this furnishes an index of the speed of ideating or forming spontaneous associations—or, in other words, of the speed of thinking.

To measure the speed of forming controlled associations an antonym test was employed. In this the pupils were supplied with a sheet containing a column of 25 key-words, opposite each of which they were instructed to write (during 85 seconds) only that word which has the opposite meaning: *e. g., better—worse; sunrise—sunset.* This test requires intelligent discrimination and demands a higher degree of associational efficiency than that required in the previous test.

In the test on the speed and accuracy of adding the pupils were supplied with a sheet containing 32 columns of figures, each column consisting of 10 one-place digits. They were told to add as many columns as possible within the time limits (2 minutes) without stopping to re-add any of the columns. This test gives a measure of the ability to form controlled numerical associations.

In the attention-perception test (A-test) a sheet was provided containing 26 lines of capital letters. The letters were printed entirely promiscuously instead of in proper alphabetical order. The pupils were told to start at the left end of the top line and proceed to draw a line through as many of the A's as possible within the time limits (100 seconds). They were specially cautioned not to skip any A's or to cross out any other letters. This test gives a measure of the speed and accuracy of perceptual discrimination, of the power of sustained attention, and, secondarily, of the speed and accuracy of manual reaction.

These five tests thus explore some of the fundamental mental traits or capacities. In all tests, and in all sittings, the pupils were uniformly urged to do their very best. A system of quantitative, or combined quantitative and qualitative, scoring was worked out for each test.

In order that tests of this character may be used as measuring-rods for gauging the increased functional efficiency resulting from the given euthenic or corrective factor or factors, a number of essential conditions must be supplied.

First, each of the tests must be constructed in sets or series, so that some of the tests may be given before the treatment begins, and some during the course of the treatment, or after its close. In this investigation each test was arranged in six sets, numbered from 1 to 6. Tests 1 and 2 were given before treatment began. The average of these two pre-treatment tests, therefore, represents the pupils' initial efficiency. The last four tests were given during the course of the treatment, or after its close, so that the average of these represents the pupils' terminal efficiency. The difference between the two averages accordingly represents the gain (index of improvement) made during the course of the treatment. Or, instead of taking the average of the last four tests for the final efficiency, we may substitute the average of the last two. This plan seems preferable, because the last two tests were given from three to five months after the dental treatment had been completed for all the pupils, while tests 3 and 4 were given only one or two months after the beginning of the treatment for more than half of the pupils. Sufficient time had, therefore, not elapsed to allow the orthogenic effects to become operative, at least not in maximal degree, at the time of the third and fourth tests.

Secondly, the sets must be so constructed that all of the successive tests in the same set are uniformly difficult. That is, test number 2 must be of the same difficulty as test number 1, test 3 the same as test 2, and so on. Manifestly, if each of the successive tests diminishes in difficulty, the increased efficiency shown is spurious or largely exaggerated. Contrariwise, if each successive test increases in difficulty the actual improvement will be minimized or counteracted. Considerable pains were taken to make all the tests of a given set equi-difficult. Elsewhere evidence has been adduced to show that the tests were fairly uniform in difficulty.

Thirdly, the conditions of giving the tests must be strictly uniform in all the successive sittings. These conditions refer to the character of the explanations, the use of incentives or suggestions, the constant putting forth of maximal effort by the examinees, the withholding of assistance or fore-knowledge of the test materials, the seating of the pupils, the hour of the day used for testing, the time allowed for the tests, and the employment of uniform supervisory conditions. A scrupulous attempt was made in this research to realize these requirements.

Fourthly, to place the results upon a strictly comparable basis, a second squad of *untreated* children should be given exactly the same tests under precisely the same conditions. These children should come from the same social strata as the treated children, should approximately be of the same ages and suffer from the same degree of physical handicap. By means of the data obtained from such an untreated squad we should be able to determine the amount of improvement which is due to such contributing factors as familiarity, habituation, practise, and natural development (merely growing older), and the share which is solely due to the application of the orthogenic factor under consideration. Unfortunately it was not possible for me to get such a squad as this organized during the experimental year.

Fifthly, and finally, the factor or factors whose orthophrenic influence is to be measured must be investigated under "controlled conditions." One must make certain that the factor is constantly operative in the treated squad, and that it is inoperative in the untreated squad. In this investigation the oral hygienic measures were subject to a fair degree of control. It was the duty of the employed nurse to see that the pupils conformed strictly to the requirements.

What, now, do the results show with respect to the influence of the dental treatment upon the working efficiency of the pupils? In attempting to answer this main question we shall also refer briefly to a number of accessory facts brought out in the investigation. One of these facts is the circumstance that while the boys manifested a higher degree of efficiency than the girls in all tests except the perception test, the indices of improvement were about the same for the two sexes, whence the boys' manifest superiority in the efficiency scores is not paralleled by a corresponding superiority in the improvement indices. Similarly the amount of improvement was about the same for the older and younger pupils, a result not entirely in accordance with expectation, for it is currently believed that the benefits derived from the correction of physical defects are greater the earlier in the child's career the defect is corrected. This is believed to be true particularly as regards nasopharyngeal obstructions. But so far as the mal-effects of dental defects are concerned there are no significant age differences. Pupils between the ages of 11 and 15 appear to profit in equal degree, irrespective of sex, from the broad application of community mouth hygiene.

On the other hand, the individual differences between the pupils in all tests are significant. The differences are quite as large as the differences frequently brought to light in other psychological and pedagogical experiments on pupils of the same age or school grade. Some pupils show a high degree, others a low degree, of proficiency; and some pupils make marvellous gains while others gain very little, or not at all, or actually lose in efficiency. It is therefore apparent that experiments of this sort, which are based on only a few pupils, are at best only suggestive, and that valid inferences or conclusions must be based on the central tendencies or average results of a considerable number of pupils.

Not only do we find these large individual differences in the efficiency scores and improvement indices, but the fact that a pupil gains much in one test does not warrant the belief that he will gain much in all the other tests. Quite the reverse may be the case. Thus a list of the 5 pupils, who made the *smallest* improvements in each of the 5 tests, was found to contain 19 of the 27 pupils, while the list of the 5 pupils, who made the *greatest* gain in each of the 5 tests, included 13 pupils. But not a single pupil was enumerated among the 5 *poorest* in *all* the tests, nor was a single pupil enumerated among the 5 *best* in *all* the tests. On the other hand, 8 of the pupils, ranking with the 5 poorest gainers in one test or another, also ranked with the 5 best gainers in one test or another. While 2 of these showed little improvement in 2 tests, they nevertheless made large gains in 2 tests. It is thus apparent that many pupils who gain little in some tests may improve remarkably in others. But it is worthy of remark that only 1 of the 3 pupils who were enumerated among the *best* gainers in *3 or more* tests was included among the *poorest* gainers, while none of the 3 who were among the poorest in *3* tests took rank with the 5 best in any of the 5 tests, so that there is a certain amount of correlation between the indices of improvement in the various tests, justifying the conclusion that pupils who improve very slowly in *several* tests will not take place with the best ground-gainers in any of the tests. Such pupils are probably suffering from general impairment or marked retardation. But teachers must recognize that a child who gains little along one line of mental action may be developing normally, or even supernormally, along other lines. His capacity for development can not be determined from the improvement indices of one trait. Scientific pedagogy will make little progress until this fact is recognized, so that the educational activities may be adjusted to meet individual developmental idiosyncrasies.

Although there are these individual differences the character of the *central tendencies* is unmistakable: there is a *decided gain* in every test, and not only are the gains decidedly more frequent than the losses, but the largest gains are invariably emphatically larger than the largest losses. This may be seen from the following data for each test, based on the average scores of tests 1 and 2, and the averages of tests 5 and 6:

Memory: 8 pupils lost in amounts varying from 5 to 15 per cent., while 19 gained in amounts varying from 0 per cent. to 116 per cent. The average gain for all pupils amounted to 19 per cent.

Spontaneous association: 2 pupils lost, the one 18 and the other 43 per cent., while 25 gained from 2 to 162 per cent. The average improvement amounted to 42 per cent.

Addition: 1 pupil suffered a loss of 13 per cent., 26 gained from 6 to 125 per cent., while the average improvement was 35 per cent.

Associating antonyms: all the pupils gained in amounts varying from 33 to 666 per cent., the average gain being 129 per cent.

Perception-attention: all gained in amounts varying from 19 to 101 per cent., the average improvement amounting to 60 per cent.

It is thus evident that the gains varied considerably in the different tests, and that the largest improvement occurred in the antonym, attention-perception, and spontaneous association tests. The average gain for all tests amounted to 57 per cent., truly a remarkably large gain.

How large a percentage of this significant gain is due solely to the improved physical condition of the pupils, which resulted from the treatment? This question does not admit of a categorical answer in the absence of parallel data from an untreated squad. But that a very large share is directly due to the dental treatment is indicated by the fact that most of these pupils were laggards or repeaters, pedagogically retarded from 1 to 4 years. During the experimental year, however, only 1 failed of promotion in the school work, while 6 completed 38 weeks' work in 24 weeks, and 1 boy did 2 years' work in 1. This indicates that the pupils' physical condition had been so bettered that they were able to profit by the instruction, to form habits from practise, and to improve mentally as a result of increasing maturity. We may therefore conclude that if it be granted that a part of the gains manifested in the psychological tests resulted from practise and increasing maturity, the gains are still significant as showing that these pupils were making normal progress during the experimental year, while many had failed to do so during the preceding year, as indicated by the records of pedagogical progress. It may be doubted, however, that the practise effects were very considerable, partly because of the brevity of the tests and the length of the intervals between some of them, and partly because of the counteracting effect of the growing monotony.

It is also significant that the regularity of attendance improved considerably during the experimental year, owing to the improved physical and mental condition of the pupils. During the preceding year many were quite irregular, because of toothaches, bodily indispositions, chronic weariness, or distaste for the school work; 5 were obliged to carry truancy cards, while during the experimental year it was not necessary to issue any of these cards; and several boys, previously regarded as "incorrigible," became tractable and gentlemanly. The improved physical and mental health of many of the pupils, which was noticed by the teachers, commented on by the parents, and fully realized by the pupils, was also made manifest in a more buoyant spirit, a healthier complexion, and an improved disposition and deportment. That a large share of the gains in the psychological tests, say at least one half on a conservative estimate, can be directly ascribed to the oral hygienic regimen, is undoubted, I believe.

This experiment, then, furnishes the first demonstration by means of controlled, serial, experimental tests, extending throughout a calendar year, of the psycho-orthogenic effects of the application of the broad principles of community mouth hygiene. The conclusions which follow from the results of the research are of far-reaching importance to the state and nation.

There is probably no phase of the modern child-welfare movement which merits deeper scientific study by qualified experts than the relation of normative physical health and growth, and of normative pedagogical and psychical development, in school children, to a well-conceived plan of physical and mental orthogenesis. No phase of the problem of national conservation or racial euthenics more nearly affects the very fundamentals of human existence. Our greatest national asset is the normal, healthy child. It would seem that our child-welfare and social-betterment workers could more profitably apply themselves to the scientific determination of the physiological, psychological, and social causes of physical and mental inefficiency, and the discovery of scientific, corrective measures on a community basis, than to devote their resources to the mere gathering of statistical data. The largest contribution to the permanent betterment of the race will be made by those workers who will undertake, on an adequate scale, genuine, scientific investigations into the actual, demonstrated effects of the application of various orthogenic measures of a physical and mental character. No such investigations are anywhere being prosecuted on an effective basis, notwithstanding that no one *knows the actual, proven effects* on the child of the application of various physical and psychological orthogenic measures or various pedagogical methods and devices. Our knowledge in this field is largely pretense and illusion. In no field of modern enterprise has there been such a lame attempt made to *measure results scientifically,* as in education. Indeed, we do not as yet so much as possess any scientific measures of educational results: the very conception of "measuring results in education" is a product of very recent industrial thinking. Is it not time that our large research foundations begin to treat more fairly the problems of human conservation and particularly those of child orthogenics? A million dollars spent in orthogenic investigations will accomplish immeasurably more for the welfare of the human race than tens of millions devoted to the cataloguing of the stars of the heavens or exploring the trackless wastes of the polar regions.

From the results of this investigation the conclusion is suggested that the desirability of establishing *dental clinics* in the public schools for free inspection and treatment should present itself to the taxpayer as a simple business, if not a humanitarian, proposition: the clinics are an economic means to an economic end, namely, the paying of proper dividends on the capital invested in the schools. According to the best estimates there are 6,000,000 retardates in the public schools of the country, or about one third of the entire school population. One sixth of all the pupils are repeaters. It costs the country $27,000,000 to educate every sixth child once, twice, or three times in the same grade. That part of this enormous waste, which is ascribable to the presence of those remediable physical defects in the children which exert a retarding influence upon the mental processes or which cause children to stay away from school, is entirely preventable. Is it worth while to attempt to save this waste? Is it worth anything to the child to enable him to attend school more regularly and thereby increase his chances of promotion? Is it worth while to the repeater to shorten his stay in the schools? Is it worth while to enable him to attain a higher level of academic efficiency? Is it worth while to remove physical obstacles which may lessen his efficiency for life? Is it worth while to the taxpayer to eliminate, so far as possible, the necessity for the extra financial burden which he must assume for instruction that should have been done satisfactorily the first time? There can be none but an affirmative answer. One of the means for accomplishing these desirable results appears to be the establishment of departments of orthogenics in the public schools. But these departments must be given a broader scope than are the present departments of medical inspection, and must be under the skilled direction of health officers who are experts in applied child or clinical psychology, corrective pedagogy, and preventive and corrective hygiene.

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